Locating Turf in the Las Vegas Valley Using Remote Sensing Techniques

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Abstract

The Southern Nevada Water Authority (SNWA) was established in 1989 by the State of Nevada to secure future water resources of Southern Nevada communities, including the fast-growing city of Las Vegas. Part of the effort to do this involves conservation of water in this dry desert community. Nearly 70% of water consumed is due to outdoor use—primarily irrigation of turf (grass). High resolution (6 inch) color infrared aerial imagery was flown in June of 2006 over the Las Vegas metropolitan area and surrounding communities. SNWA used remote sensing analysis techniques and GIS to determine the amount and distribution of turf and other vegetation within the Las Vegas Valley. Vegetation indices and newer, "non-traditional" classification techniques were employed to accomplish the vegetation and turf data extraction. GIS and common geoprocessing tools were used to examine the relationships between vegetation layers and existing municipal data.

Purpose

The purpose of identifying turf areas is directly related to the progress of SNWA's water conservation programs. In order to encourage the replacement of turf with more drought-tolerant and less water-consumptive landscape, the SNWA established the Water-Smart Landscape (WSL) program in 2002. The WSL program provides a cash incentive for a commercial and residential customers to replace turf with drought-tolerant landscape (Figure1). The total amount of turf converted peaked in 2004 but slowly declined thereafter until the cash incentives were recently increased. Currently, there is a $2/ft² cash rebate for the first 1500ft² of turf replaced, $1/ft² turf replaced up to 50,000ft² and $.50/ft² for up to 300,000 ft². The program is successful, with tens of millions of square feet of turf converted and billions of gallons of water saved annually. Still SNWA would like to refine these programs to make them more efficient in terms of cost and most effective in reaching the right demographic. The SNWA Conservation Division and Data Resources Division came up with a couple of ideas on how to approach this. We can best know how well the WSL and other lawn conversion programs are working if we know how much turf is in the valley to begin with. Also, by locating exactly where the turf is, target marketing can be used to push conservation programs in areas where larger concentrations of turf are located. SNWA determined the most efficient way of finding turf in the LV Valley was to obtain high resolution multi-spectral imagery and perform analysis that would allow wholesale identification of the areas of turf and other vegetation.

Figure 1. Photo at left shows residential landscape before WSL program enrollment. Photo at right shows same residence after conversion of turf to desert landscaping. *Photos: Courtesy SNWA Conservation Division*

Data

The high resolution (6”) digital imagery collected by Digital Mapping, Inc. (DMI), for SNWA comprised 3 bands in the blue (400-580nm), green (500-650nm) and near-infrared wavelength (675-850nm) ranges. The original data was collected as a 12-bit product using a Digital Mapping Camera System (equipped with Airborne GPS/IMU) by Intergraph-Z/I Imaging. The study area consisted of the metropolitan Las Vegas area including the cities of Boulder City, Henderson and North Las Vegas and unincorporated Clark County (including the Las Vegas Strip). The 12-bit, compressed product supplied to SNWA was ortho-rectified and tiled to match the Public Land Survey Sections of Clark County, Nevada. The image tile name corresponds to the book number and section number, which was unique to each tile. Each tile covers approximately one square mile. The study area for the turf project consists of approximately 475 tiles (Figures 2 and 3). The digital data was collected in June of 2006 while vegetation was in the peak of health.

Figure 2. Typical CIR Image tile, *DMI, June, 2006.*

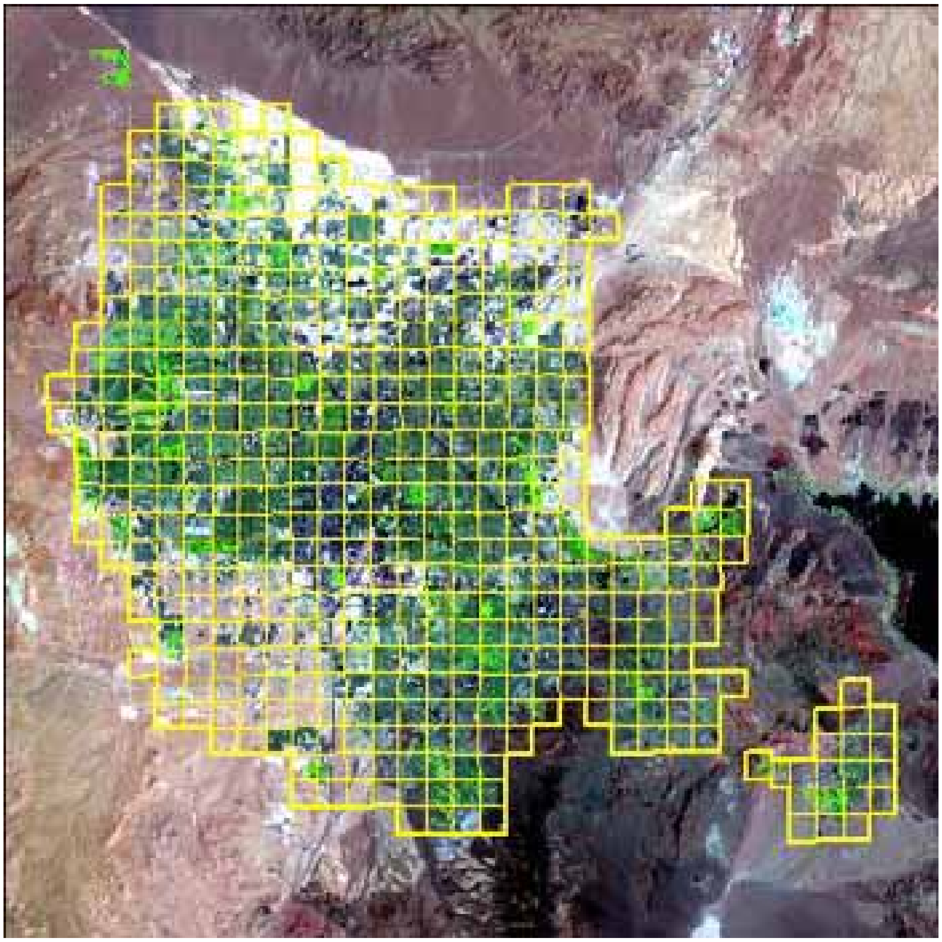

Figure 3. Landsat 5 TM (2004) image showing the Las Vegas Valley. The study area is outlined in heavy yellow and image tiles in light yellow.

Methodology

Part of the challenge of this project involved handling, processing and storage of the large quantity of original data and processed data. Approximately 3 months were spent in determining the optimum methodology for analyzing the imagery, executing the methodology and extracting the data desired.

The images were "prepared" for feature extraction before running a supervised classification. This processing was done on a Sun PC Dual Core AMD Opteron™ with an MS Windows Professional x64 operating system. In ERDAS Imagine™, the 12-bit images were rescaled to an uncompressed, unsigned 8-bit .tif dataset compatible with ArcGIS v9.1. A "diversity" neighborhood (5x5 matrix) function was performed on each image using ERDAS Imagine 9.0. The resulting 3-band "diversity" image was then summed, and the resultant single band image was stacked onto the original three band image. The diversity layer was created to incorporate and emphasize the difference in texture between turf and other forms of vegetation and to help define the boundaries between the areas (Figure 4). The 4-band image was used for the classification scheme.

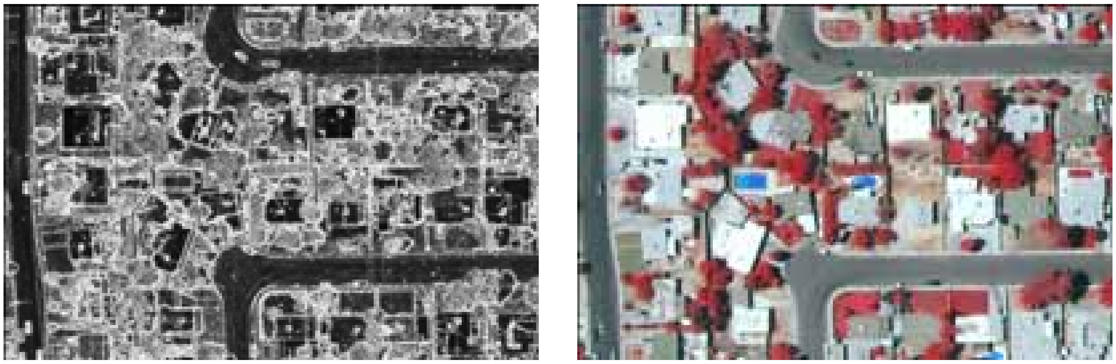

Figure 4. The image at left shows the diversity layer, the image at right shows the same area in the original 3-band image.

The digital image data was collected over a period of two weeks, and was flown at different altitudes due to flying restrictions in some parts of the study area. This, and other factors such as the urban-suburban nature of the terrain, the type of soil in the LV Valley and the amount of land "under construction" caused some tiles to have a high degree of color and texture variation within them (Figure 5). From tile to tile the variation could also be quite dramatic. This made it necessary to produce a mosaic image suitable for creating a classification training set that would produce a good supervised classification. Six adjacent images, oriented perpendicular to the flight lines, were mosaicked using Imagine. The neighborhood diversity analysis was then done on the mosaic image, and the summed results stacked into the mosaic to make a 4-band image ready for "training".

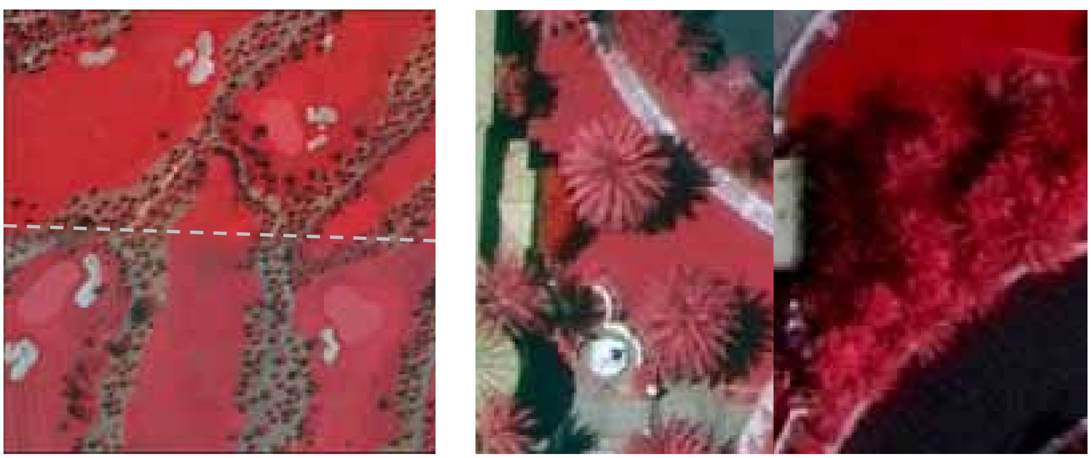

Figure 5. The image on the left is an example of color variation within a single image. Here the image is a mosaic of data collected on two different days or times of day. The images on the right, shown at the same scale, illustrate color and texture differences from image to image.

The Visual Learning Systems' Feature Analyst™ extension for ArcGIS was used in image classification. The goal of the classification was to bring out three classes of cover: trees (including shrubs), turf and vegetation in shadows. These three were chosen because the goal of the project was to extract turf from the image including turf in shadow areas (between buildings, in tree shadows, etc.) and to learn about the relationship with or association with other vegetation. The imagery was of high resolution, therefore, no field work was needed to determine training areas. From examination of the imagery it was clear that some types of trees appeared very similar to some areas of turf, and some types turf were very different from each other. To the extent possible, when choosing the training areas, the entire range of color and texture in each class was used. Because of the quantity of the images, the time required for processing and project deadlines, there was not time to “clean up” the classification for individual images, combining classes, etc. The approach was to come up with the best training set and model, run the classification on every one of the 475 images, perform an accuracy assessment and present the results before the deadline.

The Feature Analyst™ extension for ArcGIS v9.1 (ArcMap) was used for the supervised classification. This software was selected because of its ability to extract the turf, tree and shadow classes efficiently. In the urban landscape, the vegetated areas can be seen as “objects” or “features”, which the Feature Analyst software was able to extract relatively well in a one-step process. Using the mosaic image mentioned previously, 25-30 training polygons were identified for each class and were merged into a single training shapefile. The classification model used was for the extraction of natural features (for example, trees) and the search pattern for detection of classes was a “bulls-eye 3”, 13 pixels wide. The aggregate sample size was 225 pixels, which means that groups of “qualified” pixels smaller than this were not classified. Only the qualified pixel groupings were classified and appear in the resultant dataset.

Many classifications with different patterns, feature models and pixel numbers were tried on a sampling of the images. The *total processing time* was noted and the classification results were compared to the imagery. It was this “trial and error” process that determined the necessity of adding the neighborhood analysis band to the original image for classification and creating the mosaic image to handle the variation in color and texture. It eventually determined the final model for the analysis. Once the classification model was chosen, the images were batch-processed using the mosaic training set model.

The dataset resulting from the Feature Analyst™ classification process is a single shapefile containing each of the separate class polygons. Each class is identified by a specific attribute and can be symbolized in ArcMap as such. After the classification, the 475 shapefiles needed some work to determine which shadows were likely turf (in shadows), which were shadows in tree canopies and which would have no association with vegetation. Also, the data needed to be related with other GIS data that would be useful in determining, for instance, which housing developments had more turf per residence, or which homeowners had copious amounts of turf and vegetation in their yards.

Using the Modeler in ArcToolBox a single geoprocessing model was constructed. The model was then exported to a Python script to enable looping through the 475 tile shapefiles. This work was challenging. “Memory leaks” were common to ArcGIS 9.1 and this frequently caused the script to “bomb out”. With the advent of ArcGIS 9.2, the memory leaks were no longer problematic and the script ran smoothly through all of the datasets. The scripts had to be run on a 32bit Intel Pentium processor machine with MS Windows XP Professional™. A 64-bit dual core machine was available, but the Python script with the ArcGIS 9.2 geoprocessing tools do not work in a 64-bit OS.

The model/script completed all of the necessary steps required to finalize the data. It integrated the vegetation data with the most current Clark County Assessor's Office parcel data and distributed shadow polygons into classes of "tree", "turf" or "neither" (Figure 6). The criteria for determining whether shadows belonged to the tree or turf class were as follows: If a shadow polygon was within 6 pixels of a turf polygon it was considered turf. Of the remaining shadow polygons, if the polygon was within one pixel of a tree polygon, it was then considered a tree. Any remaining polygons were considered non-vegetation. The ArcGIS "select by location" geoprocessing tool was used to accomplish this task within the script.

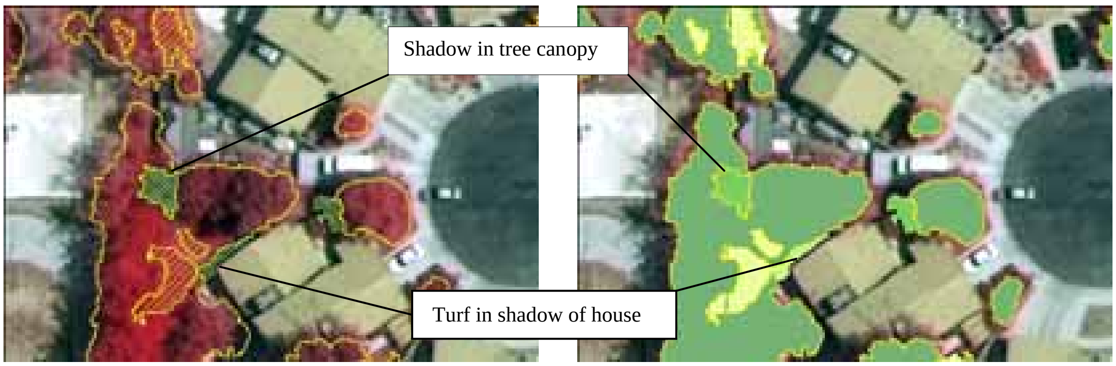

Figure 6. The figure on the left shows the original classification data, with grass showing as hatch, trees as a yellow outline and shadow as a double hatch. On the right the grouping of the shadows into respective turf and tree classes is complete, with trees shown in green and turf in yellow.

The five digit combination of the book and section number of the public land survey is an attribute in the parcel layer and was, by design, part of the name of the image and resulting image classification shapefile. This facilitated a selection of the parcel layer data corresponding to the image data area and enabled the use of the ArcGIS intersect tool to combine parcel layer with the image class data (Figure 7). After the intersection, the class polygons had all of the attributes of the parcel data as well as the veg-type information. The parcel number is important for linking the vegetation data to many types of municipal data and enables the SNWA to conduct a market analysis for the Water Smart Landscape turf reduction program.

Geoprocessing time was 15-20 minutes per dataset because the polygons produced from the analysis had a very large number of polygons and vertices. Edges of polygons were simplified (vertices removed) to facilitate some of the processes. However, the final product had all of the original vertices.

The final datasets for each image tile included one tree shapefile, one turf shapefile, one shadow shapefile, one shadow shapefile that would be merged with the trees, and one shadow shapefile that would be merged with the turf. The shadow datasets were "manually" merged with the respective turf and tree datasets using the batch mode in ArcGIS v9.2. The 475 turf and tree "section tile" datasets were then merged by book number and imported into personal geodatabases and polygon feature classes. Each polygon feature had a parcel number as an attribute to enable joining with other municipal data containing property owner information, land-use information and water consumption data.

Figure 7. This image is overlain by turf polygons in yellow hatch, tree polygons outlined in yellow and parcels outlined in blue. Some parcel boundaries are in the front yards, showing how the imagery did not perfectly line up with GIS layers

Accuracy Assessment

While examining the classification results, it became clear there were some errors in the classification (Figure 8). In order to determine the extent of any errors and the accuracy of the data, an accuracy assessment was performed. Using ArcGIS, random points were generated over the entire study area in each of three cover types: turf, tree and non-vegetation. The non-vegetation area essentially consisted of everything that was not previously classified as tree or turf. The pixel at each point location was examined using the imagery available. The high resolution imagery enabled positive identification of over 95% of the points. A very small percentage of the points had to be identified in the field. Field identification was somewhat biased because of accessibility issues. Only front yards of private properties and public property could be accessed well enough for a firm identification in the field. An error matrix was generated as the accuracy data was accumulated. As shown in Table 1, a total of 1417 point locations were examined. Based on the producer and user error shown, this data was given a very acceptable level of confidence.

Figure 8. The tree polygons are outlined in yellow along the roadway. Some of the polygons extend beyond the tree canopy and overlap the roadway.

	Turf	Tree	Non-vegetation	Row Total	User Error
Turf	321	49	1	371	86.52%
Tree	28	489	9	526	92.97%
Non-vegetation	10	25	485	520	93.27%
Column Total	359	563	495	1417	
Producer Error	89.42%	86.86%	97.98%		
Overall Accuracy (total right/total)					91.39%

Table 1. Error/Accuracy matrix

Data Application

The accuracy assessment confirmed that the data is meaningful and usable for analysis. The SNWA will be able to put the turf and tree data to good use by linking the data, using the parcel number as the primary field. The ability to join to parcel data enables the determination of which parcels have the densest cover of turf or vegetation and provides information on the parcel owners. A market analysis can be done, and target marketing can focus promotion of turf reduction programs on those customers with the most turf. Using the GIS data to identify turf in medians and rights-of-way, SNWA can target municipalities that may still be maintaining turf in these areas. The data also can also link to consumption data, which would allow for an examination of the relationship between landscaping type and total water consumption for a parcel. This could help confirm whether the focus of the conservation efforts is where it should be.

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